U.S. Department of the Interior **U.S. Geological Survey**

INTRODUCTION

This publication portrays the geology of the Hardeeville NW quadrangle and parts of the Brighton and Pineland quadrangles that are within Jasper County, South Carolina. This study area is located in the Atlantic Coastal Plain province, approximately 50 to 70 kilometers (km) inland from the coast. The data are compiled from geological field mapping, light detection and ranging (lidar) elevation data, cores, optically stimulated luminescence (OSL) ages, radiocarbon ages, and biostratigraphic interpretations. Most of the study area is occupied by the valley of the Savannah River, and exposures of geologic units are very limited. Traditional geologic mapping in this area is difficult because of limited access, subdued topography, extensive swamps, and abundant vegetation.

The Savannah River flows predominantly southeast, and forms most of the border between the States of South Carolina and Georgia. The river is approximately 483 km long, and has a total drainage area of approximately 15,850 square km (km²). Although upstream tributaries drain the southeastern side of the Appalachian Blue Ridge province, the Savannah River begins in the Piedmont province and then flows across the Atlantic Coastal Plain province to the Atlantic Ocean. For much of its extent, the modern channel of the Savannah River is located on the southwestern side of the river valley, and the southwestern bank of the valley is the active cut bank. Within the study area, the valley of the Savannah River trends southeast and is relatively straight. The valley has relatively low relief, although the southwestern valley wall is steeper and has greater relief than the northeastern valley wall. Elevations within the valley mostly range from 3 to 15 meters (m) above sea level, whereas elevations on the high terrace that forms the eastern margin of the Savannah River valley are 15 to 20 m above sea level. The width of the valley is 6 to 7 km in the northern part of the study area, and expands to 10 to 12 km farther south. The modern river channel occupies the southwestern side of the valley, and some modern (active) creeks enter the river from the west. Sand hills and low-relief terraces are present to the east of the modern river channel, and the eastern side of the valley is characterized by abandoned meandering and linear channels. Fan-shaped deposits of sand and mud are present where relict (inactive) channels enter the eastern side of the valley. Abandoned meandering channels of low relief (<3 m) are also present to the east on the high terrace (>15 m elevation) that forms the eastern margin of the Savannah River valley. Within the study area, most of the Savannah River valley is covered by alluvial wetland community vegetation dominated by cypress and tupelo trees, although sand hills within the valley are covered by xeric sand community vegetation dominated by pine trees (Christensen, 2000; Bernhardt and others, 2012).

PREVIOUS WORK

Most early studies of the major geomorphological features of the Savannah River valley may be found in publications of broader studies of the geology of the Atlantic Coastal Plain (McGee, 1890, 1891; Veatch and Stephenson, 1911), and some early geomorphological descriptions may be found in publications of primarily botanical focus (Bartram, 1791; Harper, 1903, 1904, 1905). Nevertheless, most of these early studies provide general descriptions of the valley, and they report the presence of terraces, sand ridges, and sand hills.

Specific studies of terraces within the Savannah River valley are relatively few. In Aiken and Barnwell Counties, Siple (1967) noted the presence of terraces, and Leeth and Nagle (1996) described the following two mappable units within the valley: (1) a 6.7- to 13.7-m-thick unit of "modern" alluvial sediments on the western side of the flood plain, and (2) a 1.5- to 8.5-m-thick older alluvial terrace complex on the eastern side of the flood plain. The two units overlie an unconformity above Eocene strata, and the total thickness of these two units decreases towards the coast. In Jasper County, the U.S. Department of Agriculture (USDA) soil survey (Stuck, 1980) characterizes the terraces within the Savannah River valley as primarily a mixture of sandy loam and clayey loam named the Santee association, whereas a few small areas are described as either a mixture of clayey loam and sandy loam named the Argent-Okeetee association or a mixture of sandy loam and sandy clay named the

In contrast with the terraces, the sand ridges and sand hills within the Savannah River valley have been the subject of more intensive study. McGee (1890, 1891) and Veatch and Stephenson (1911) reported the presence of sand hills and provided brief descriptions. In the USDA soil survey of Jasper County (Stuck, 1980), the area of the main sand hills within the Savannah River valley is mapped as a sandy soil named the Buncombe association, and the areas of isolated sand hills and ridges are mapped as a mixture of sandy soil and sandy loam named the Buncombe-Santee association. Pickering and Jones (1974) and Markewich and Markewich (1994) interpreted the sand hills as vegetated, parabolic eolian dunes. Leigh and others (2004) described south- to southeast-trending linear ridges in the Savannah River valley at approximately 32°22'50" north latitude, and they interpreted these features as fluvial "braid bars that have been reworked by the wind to produce parabolic dunes." They also described these features as "a braided terrace that is reworked and overlain by parabolic dunes." Bernhardt and others (2012) described pollen assemblages from Holocene sediment that had accumulated between sand hills (see vibracore C3 location on maps A and B). Swezey and others (2013) published a detailed study of the sand hills, and they agreed with previous interpretations of the hills as parabolic eolian dunes that are derived from sand of the Savannah River and that are stabilized by vegetation under prevailing climate conditions. In addition, they published OSL ages that suggested that most of the eolian dunes were active during the last glacial maximum (LGM) through early deglaciation, and they used a variety of data to infer paleoclimate conditions (wind direction, velocity, precipitation, evapotranspiration, vegetation cover) when the dunes were active. They also demonstrated that the Savannah River dunes are part of a larger assemblage of eolian dunes that were active in river valleys of the eastern United States during and immediately after the

Geologic maps of the South Carolina parts of the Brighton, Hardeeville NW, and Pineland quadrangles were published by Doar (2008, 2013a, b) as part of the STATEMAP component of the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping Program. These maps show a variety of geologic units including terraces, marsh and swamp deposits, fluvial and alluvial sediments, and eolian dune ridges and hills. However, the work for these maps was completed before the widespread use of lidar imagery, and therefore they do not display the amount of detail that is visible in the lidar shaded-relief image (map B). This publication adds details to the existing geologic maps by Doar (2008, 2013a, b), and provides additional data derived from geologic field mapping, lidar elevation data, cores, OSL ages, radiocarbon ages, and biostratigraphic interpretations.

SUMMARY OF MAP UNITS [Abbreviations: "14C yr BP" indicates radiocarbon years before present, where "present" is

defined as A.D. 1950; "cal yr BP" indicates calibrated radiocarbon years before present. Preferred OSL ages are shown in bold fonts in table 1 and explained in the table 1 headnote. Conversions from radiocarbon years to calibrated radiocarbon years were made using the program CALIB 6.1.1 (accessed at http://calib.qub.ac.uk/calib/), in conjunction with Stuiver and Reimer (1993) and Reimer and others (2009)]

Within the study area, the various map units are grouped into the following five broad categories on the basis of age and sediment composition: (1) Quaternary (Holocene) sand and mud, with or without peat (Qsmp1, Qsmp2, Qsm1, and Qsm2) are interpreted as fluvial and swamp deposits. Some of the sediments in this category have accumulated in topographic depressions among the sand hills, and thus must be younger than the sand hills that have yielded preferred OSL ages ranging from approximately 35.4 to 18.0 ka (kilo-annum, or thousand years before present) (table 1). Samples from vibracore C3 (maps A and B) in one of these depressions have yielded radiocarbon ages ranging from 8,275±30 ¹⁴C yr BP (9,403 to 9,135 cal yr BP) to modern (fig. 4; table 3). Other sediments in this category consist of fluvial sediments and swamp sediments associated with the lowest and westernmost terrace (Qt0), which is the terrace that is closest to the modern Savannah River. The Holocene age for these units is provided by the observation that meandering channels on terrace Qt0 have cut laterally into the

western margins of both the sand hills and terrace Qt1. (2) Quaternary sand (Qs1) that forms sand hills is interpreted as degraded eolian dunes stabilized by vegetation under prevailing climate conditions. Detailed descriptions and analyses of these sand hills are given in Swezey and others (2013). Sediments in this category generally form one relatively continuous group of sand hills that is located at distances of 0 to 5 km from the modern river channel, and covers an area that is approximately 15 km long and 0.2 to 3.2 km wide. Where discernible, the morphologies of individual hills range from parabolic shapes (with tails pointing west) to isolated circular and linear shapes. In addition, several isolated sand hills and northwest-trending ridges are present in the southern part of the study area at distances of 2 to 6 km east of the modern river channel (maps A and B). As discussed in the following section, the lidar image (map B) shows that the relatively continuous group of sand hills (Qs1) overlies parts of terraces Qt1 through Qt5, implying that the terraces are older than the sand hills. Using the preferred OSL ages given in bold in table 1 and taking into account the reported ranges of uncertainty, 13 samples from 11 locations within the relatively continuous group of sand hills have yielded OSL ages ranging from approximately 35.4 to 18.0 ka, and two samples from relatively isolated sand hills have yielded preferred OSL ages ranging from approximately 11.0 to 9.5 ka (GAW-13 and GAW-11; table 1). (3) Quaternary (Pleistocene) sand and mud, with or without gravel or peat (Qgsm, Qsm5, Qs3, Qsmp4, Qsmp3, and Qs2) are interpreted as alluvial, fluvial, and swamp deposits. The sediments of this category lie within the Savannah River flood plain to the east of the lowest and westernmost terrace (Qt0). Some of the units

of this category form distinct terraces (Qt1 through Qt5), whereas others form alluvial fans on the east margin of the flood plain, and yet others occupy abandoned fluvial channels that are truncated by younger sediments. These sediments are thought to be Quaternary in age, spanning a time that ranges from older than the sand hills (eolian dunes, Qs1) to coeval with the sand hills. For example, the lidar image (map B) shows that the relatively continuous group of sand hills overlies parts of terraces Qt1 through Qt5, implying that the terraces are older than the sand hills. Indeed, one sample of sand (GAW-37; table 1) collected from a depth of 183 centimeters (cm) below the surface of terrace Qt4 yielded a preferred OSL age of approximately 108±12.0 ka, which is much older than the preferred OSL age range

of 35.4 to 18.0 ka for the sand hills (table 1). However, some of the preferred OSL

This study | Outcrop description

ages from the terraces are coeval with the preferred OSL ages from the sand hills. For example, (1) a sample of sandy mud (GAW-29; table 1) collected from a depth of 61 cm below the surface of terrace Qt5 yielded a preferred OSL age of 39.7±3.6 ka, (2) a sample of sand (GAW-14; table 1) collected from a depth of 70 cm below the surface of terrace Qt4 yielded a preferred OSL age of 24.2±1.2 ka, and (3) a sample of sandy mud (GAW-28; table 1) collected from a depth of 84 cm below the surface of terrace Qt4 yielded a preferred OSL age of approximately 23.6±2.1 ka. In addition to the terraces, sediment in this category is found in the southern part of the lidar image (map B), where a 50- to 130-m-wide southwest-trending channel (Qsmp4) is incised into terraces Qt1 through Qt5, and is buried by the sediment of terrace Qt0. Gouge core C1 that was drilled in the upper reaches of this channel (maps A and B; fig. 4) recovered 1.37 m of sand, sandy mud, and muddy sand. A sample of wood (WW8888; table 3) from muddy sand at the base of gouge core C1 yielded a radiocarbon age of 41,890±930 ¹⁴C yr BP (46,841 to 43,856 cal yr BP). This age approaches the older limit for radiocarbon dating, and therefore may be a minimum

age for the sample (and a minimum age for the channel). (4) Neogene (lower Pliocene?) mottled gray, brown, and orange gravel, sand, and mud without phosphate grains (Ngsm). Sediments of this category are exposed at one outcrop on the Savannah River near the northwesternmost part of the geologic map (map A) and lidar image (map B) (sample location GAW-31; photographs 1 and 2), and were encountered at depth in drill core C2 and all auger cores (figs. 2 and 3). At this outcrop on the river (described in greater detail in Swezey and others, 2013), a 4-m-thick unit of sand (sand hill, Qs1) overlies an unconformity that caps a 1.5-m-thick unit (Ngsm) of partially indurated, mottled reddish-brown to light-gray, fine-grained quartz sand with a few thin beds and laminations of gray to white mud. This unit of reddish-brown to light-gray sand and mud, overlies a >1-m-thick unit of partially indurated, dark-yellowish-orange, poorly sorted, coarse to fine quartz sand with crossbedding. At this location, sample GAW-31 (table 1) from the reddish-brown to gray sand (Ngsm) beneath the sand hill yielded an OSL age of >43 ka. A similar occurrence is present in drill core C2, where 2.6 m of sand of the sand hills (Qs1) overlies an unconformity that caps a 1.4-m-thick unit (Ngsm) of partially indurated, mottled light-gray to reddish-brown sandy mud (fig. 2). This unit of sandy mud overlies a >1.2-m-thick unit of partially indurated, pale-reddish-brown to dark-yellowish-orange fine to coarse quartz sand. The sediments of unit Ngsm also comprise the high terrace (>15 m elevation)

that forms the eastern margin of the Savannah River valley (east of terrace O5). In the lidar image (map B), this high terrace displays a series of relict meandering channels and it is presumed that these channels are filled with Quaternary sand and mud (Qsm3 and Qsm4). The sizes of the relict meandering channels are similar to those of the modern Savannah River, suggesting similar flow regimes. There is some uncertainty about the stratigraphic name that should be applied to mapped unit Ngsm. The strata are similar in both appearance and stratigraphic

position to strata that have been described on the west bank of the Savannah River. For example, at Sisters Ferry Landing on the west side of the river (immediately west of auger core HNW-9), Lyell (1845) reported the presence of Cenozoic brick-red loam, red and gray clay, and beds of steatitic clay. At an outcrop at Porters Landing on the west bank of the Savannah River, approximately 7.4 km northwest of the northwesternmost corner of Jasper County (northwestermost point on maps A and B), several geologists have provided descriptions of measured sections but have assigned different stratigraphic names to the units (fig. 1). At this Porters Landing outcrop, there is an upper unit of white, red, and yellow, fine to coarse sand with crossbedding and some beds of clay that has been assumed to be Pleistocene in age

by geologists who have worked primarily in South Carolina (Sloan, 1908; Cooke,

1936; Malde, 1959). Cooke (1936) tentatively assigned these strata at Porters Landing to the Pleistocene(?) Sunderland(?) Formation. This formation was named by Shattuck (1901) after a site in Calvert County, Maryland, but the name is now considered to apply only to a geomorphic feature and has been abandoned as a stratigraphic term (Huddlestun, 1988). In contrast, Huddlestun (1988) worked primarily in Georgia, and he designated this unit of fine to coarse sand at Porters Landing as the Pliocene Cypresshead Formation, which has its type locality in Wayne County, Georgia (Huddlestun, 1988). More recently, Doar (2008) mapped these strata of post-Miocene and pre-Quaternary fine to coarse sand in the Hardeeville NW quadrangle as the Pleistocene Ladson Formation, which has its type locality in Charleston County, South Carolina (Malde, 1959). However, Doar (2013b) mapped these strata of post-Miocene and pre-Quaternary fine to coarse sand in the Pineland quadrangle as the Pleistocene Penholoway Formation. This formation was named by Cooke (1925) after a site in Wayne County, Georgia, but the name is now considered to apply only to a geomorphic feature and has been abandoned as a stratigraphic term (Huddlestun, 1988). Furthermore, Huddlestun (1988) stated that the Penholoway terrace is an erosional terrace that has been cut on the Cypresshead Formation. In summary, different stratigraphic names have been applied to post-Miocene and pre-Quaternary fine to coarse sand at different locations, and it seems likely that some or all of these names refer to the same unit. (5) Neogene (lower Miocene) sand and mud with phosphate grains (Nsm). Sediments of this category are not exposed in outcrop within the study area, but they were encountered in drill core C2 and all auger cores (figs. 2 and 3). These sediments are capped by an unconformity, above which lies lower Pliocene(?) mottled light-gray and pale-reddish-brown sand and mud (Ngsm). The lower Miocene age of this unit is indicated by biostratigraphic data from sample R6709 A (table 2).

similar in both appearance and stratigraphic position to strata that have been described at the outcrop at Porters Landing, although geologists have given different names to the strata at this outcrop (fig. 1). At Porters Landing, the lower units of the outcrop are predominantly sandy mud and muddy sand with phosphate grains, and were designated by Cooke (1936) and Malde (1959) as the lower Miocene Hawthorn Formation (which has its type locality in Alachua County, Florida; Dall and Harris, 1892) and the overlying upper Miocene Duplin Marl (which was named for outcrops in Duplin County, North Carolina; Dall, 1898). Malde (1959), however, noted that the Duplin Marl has distinct marine fossils but very little lithologic uniformity, and he recommended that the name be abandoned. Likewise, Blackwelder and Ward (1979) noted that the Duplin Marl was defined on biostratigraphic data rather than lithologic data, and they recommended that the name be abandoned in favor of the name Yorktown Formation (which has its type locality in York County, Virginia; Clark and Miller, 1906). In contrast, Huddlestun (1988) designated the lower units at Porters Landing as lower Miocene strata of the Parachucla Formation (which has its type locality in Effingham County, Georgia) and the overlying Marks Head Formation (which also has its type locality in Effingham County, Georgia; Sloan, 1908). Both the Parachucla Formation and the Marks Head Formation are mapped by Huddlestun (1988) as part of the Hawthorn Group.

Like the overlying lower Pliocene(?) unit Ngsm, there is some uncertainty about

the stratigraphic name that should be applied to mapped unit Nsm. The strata are

DISCUSSION

The sediments and strata preserved in the study area reveal an interesting history of landscape evolution since the Miocene. The lower Miocene unit of sand and mud with phosphate grains (Nsm) is interpreted as a shallow marine deposit that accumulated when sea level was high enough to flood the study area. The presence of phosphate in the Miocene strata may be attributed to the reworking of older phosphate-bearing strata and (or) to the warming of phosphate-rich marine water that would have caused a subsequent loss of CO₂ and an increase in pH. Such conditions of warm phosphate-rich marine water tend to occur in shallow-water areas of upwelling in the trade wind zone (Cook and McElhinny, 1979; Föllmi, 1996). The unconformity above the lower Miocene strata may or may not be regional in extent. Brief but significant falls in eustatic sea level during the middle Miocene and late Miocene have been identified in studies by Haq and others (1987), Van Sickel and others (2004), Miller and others (2005), and Swezey (2009). The overlying lower Pliocene(?) gravel, sand, and mud (without phosphate grains) (Ngsm) is interpreted as a fluvial to estuarine to marginal marine deposit. As such, it represents the progradation of terrigenous sediment into the study area. An early Pliocene age is the best interpretation for this unit, with the overlying unconformity being the result of a major eustatic sea-level fall caused by the onset of glaciation in the northern hemisphere. As outlined by Shackleton and others (1984), Haug and others (1999), Prueher and Rea (2001), and Maslin and others (1998, 2001), the sudden increase in ice-sheet extent in the northern hemisphere occurred at approximately 3.1 to 2.5 Ma (mega-annum, or million years before present). After the onset of glaciation, the study area would have become a site of sediment bypass and erosion, as sediments were carried farther east to the new (lower) sea-level position. Any exposed sediments in the area would have been subjected to weathering (which would

account for the mottled appearance of the lower Pliocene(?) gravel, sand, and mud) and bioturbation by plants (which would account for lack of obvious primary sedimentary structures in many of the mapped units of the study area). During the past 2.5 million years, ice sheets have waxed and waned, but the only sediments preserved in the study area from this time interval are (1) Quaternary eolian dunes and various fluvial and alluvial sediments that date from approximately the Last Glacial Maximum (LGM), and (2) Holocene sand and mud that are predominantly fluvial and swamp deposits. As outlined by Swezey and others (2013), most of the Quaternary eolian sediments were active during the LGM when the climate was more arid, wind velocities were much greater, and vegetation cover was less dense. During this time, the Savannah River is thought to have been active enough to have mobilized and deposited some fluvial sediment, but this activity was more ephemeral than at present. During the Holocene, however, as ice sheets have retreated and sea level has risen, the study area has changed from an area of fluvial sediment bypass and erosion to an area of fluvial (and swamp) sediment accumulation. As these changes have occurred, the climate has become more humid, wind velocity has decreased, and vegetation cover has increased. As a result, the eolian sediments have

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Minimum Age Model-3 (MAM) (Galbraith and Laslett, 1993; Galbraith and others, 1999)]

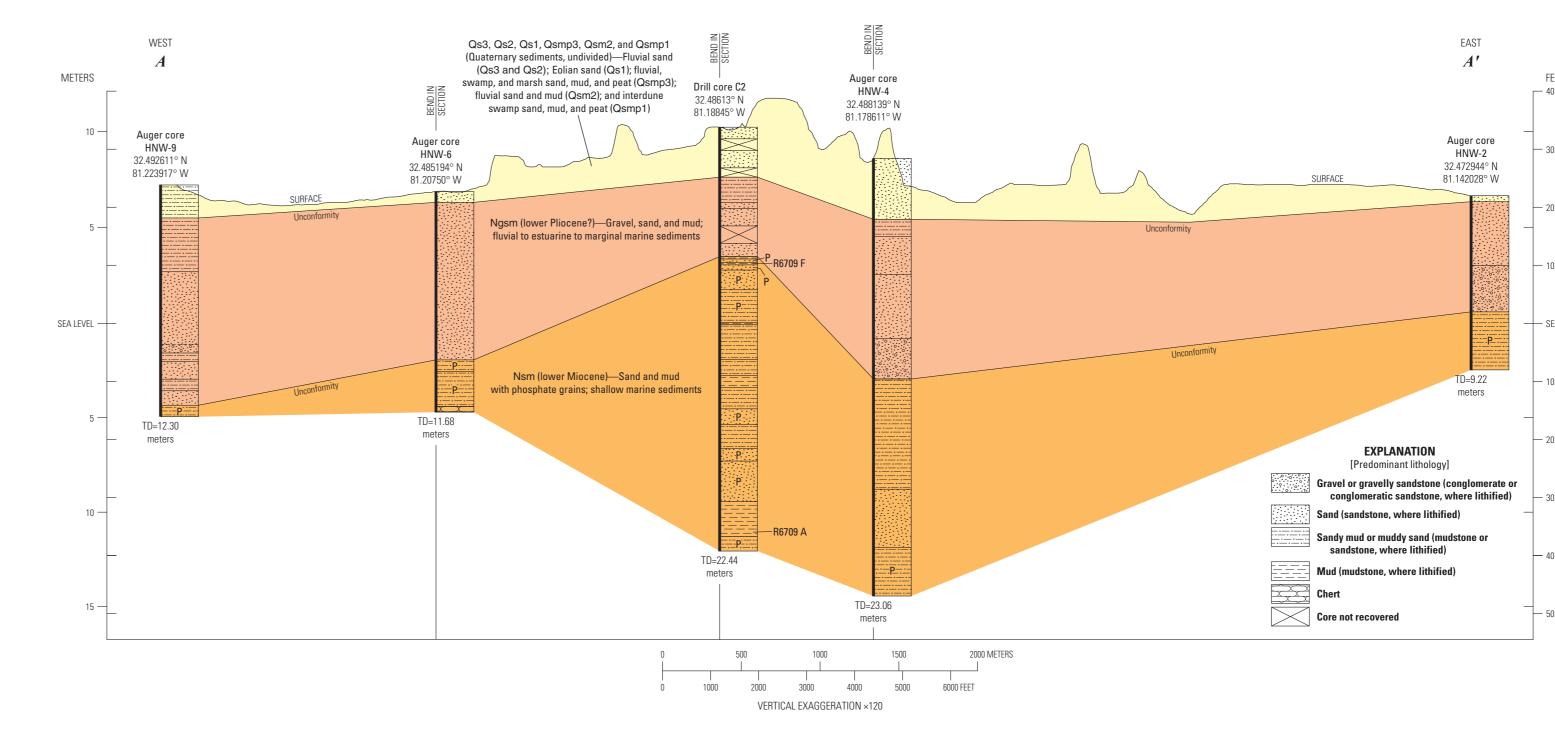


Figure 2. Cross section A-A' constructed using auger and drill core data. R6709 F and R6709 A are U.S. Geological Survey identification numbers for two samples from drill core C2 from which dinoflagellate species were identified for biostratigraphic age control (table 2). Auger and drill core locations are shown with heavy dark vertical lines; core widths are exaggerated to show lithologies. Dashed contact in auger core HNW-9 is gradational. Abbreviations: HNW, Hardeeville Northwest; N, north; P, sediment containing phosphate sand grains; TD, total depth of auger or drill core from surface elevation; W, west

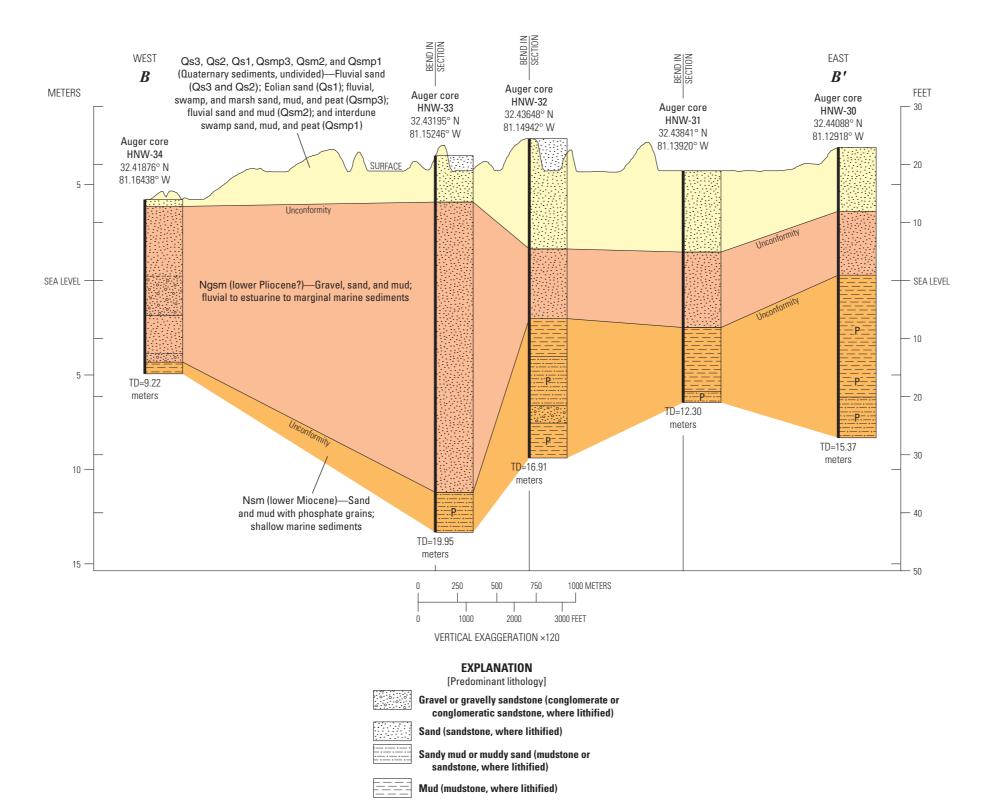
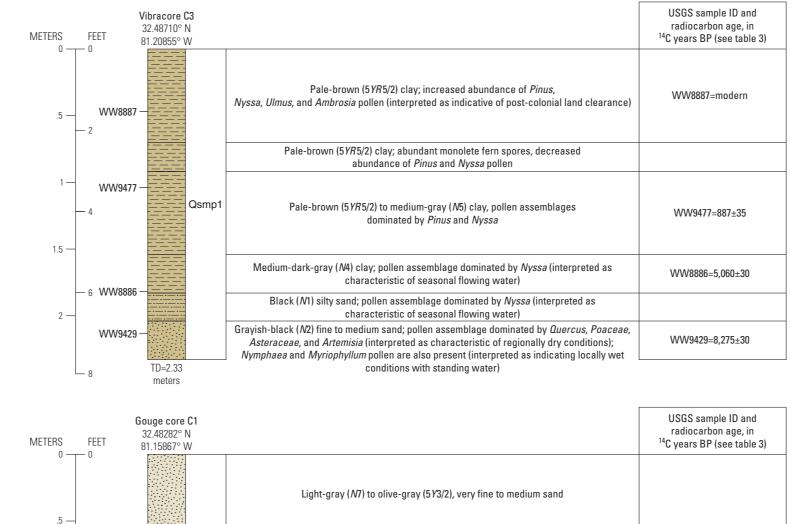


Figure 3. Cross section B-B' constructed using auger core data. The lower Miocene age estimate for unit Nsm was determined from biostratigraphic data from drill core C2 (fig. 2; table 2), and extrapolated to cross section B-B' located in the southern part of maps A and B. Auger core locations are shown with heavy dark vertical lines; core widths are exaggerated to show lithologies. Dashed contacts in auger core HNW-34 are gradational. Abbreviations: HNW, Hardeeville Northwest; N, north; P, sediment containing phosphate sand grains; TD, total depth of auger core from surface elevation; W, west.



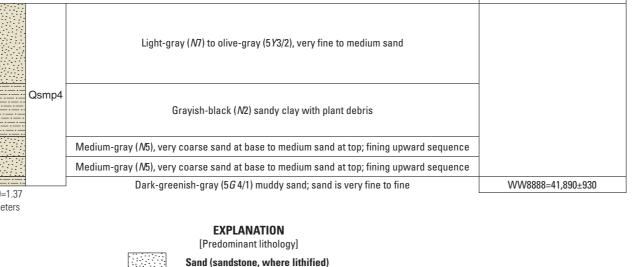
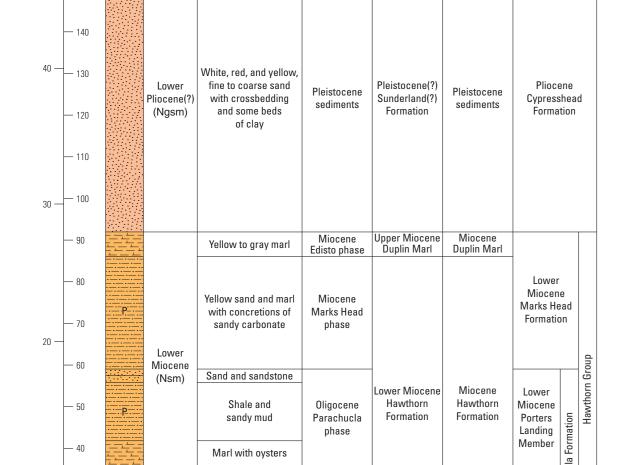


Figure 4. Stratigraphic column descriptions of vibracore (C3) and gouge core (C1) with radiocarbon ages. Locations of cores C3 and C1 are shown on maps A and B. Color nomenclature (for example, 5YR 5/2) used in core descriptions is from Goddard and others (1963). Abbreviations: ¹⁴C years BP, radiocarbon years before present, where "present" is defined as A.D. 1950; N, north; TD, total depth of core from surface elevation; USGS sample ID, U.S. Geological Survey sample identification number; W, west.

Sandy mud or muddy sand (mudstone o

sandstone, where lithified)

Mud (mudstone, where lithified



Sloan (1908)

(1936)

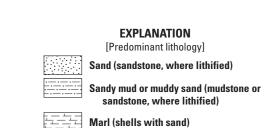
(1959)

(1988)

Miocene

Tiger

Member



Combahee

Gray sandy mud

Figure 1. Measured section of an outcrop at Porters Landing on the west bank of the Savannah River, as described and interpreted by Sloan (1908), Cooke (1936), Malde (1959), and Huddlestun (1988). The outcrop is located approximately 7.4 kilometers (4.6 miles) northwest of the northwesternmost part of maps A and B. Note that different stratigraphic designations have been applied to the lithologic units identified at the outcrop by Sloan (1908), Cooke (1936), Malde (1959), and Huddlestun (1988). The term "phase" was used by Sloan (1908). For a discussion of the lithologic units and their relation to cross section A-A', see "SUMMARY OF MAP UNITS." Elevations shown on the scale are given as units above sea level Abbreviation: P, sediment containing phosphate sand grains.

Table 1. Optically stimulated luminescence (OSL) sample data and age results from Swezey and others (2013). [Explanation of table columns are as follows: "OSL sample ID" is the optically stimulated luminescence sample identification number; "Sample elevation, in meters" is the elevation of the sample location, in meters above sea level; "Sample depth, in centimeters" is the sample depth, in centimeters below surface; "Water, in percent" is the laboratory measured field moisture (water content) of the sediment at the center of each tube in which the sample was collected (sample saturation percentage is in parenthesis); "K, in percent" is the potassium concentration; "U, in ppm" is the uranium concentration, in parts per million; "Th, in ppm" is the thorium concentration, in parts per million; "CDA, in Gy/k.v." is the sample cosmic dose addition, in grays per thousand years, as calculated using the methods of Prescott and Hutton (1994); "Dose rate, in Gy/k.y." is the total dose rate, in grays per thousand years; "DE, in Gy (MAM)" is the sample equivalent dose, in grays, using the Minimum Age Model-3 (MAM); "DE, in Gy (weighted)" is the sample equivalent dose, in grays, using the weighted mean; "DE, in Gy (mean)" is the sample equivalent dose, in grays, using the mean; "nDE (mean)" is the number of replicated equivalent dose estimates used to calculate the mean value (number in parenthesis represents the total number of measurements of subsamples or aliquots, including failed runs with unusable data); "Dispersion, in percent" is the calculated average of the equivalent dose divided by the standard deviation of the equivalent dose, without evaluating the ranges of uncertainty; "OSL age, in ka (MAM)" is the determined age of the sample in thousands of years before present using the OSL Minimum Age Model-3 (MAM) for equivalent dose determination (preferred ages in bold); "OSL age, in ka (weighted)" is the determined age of the sample in thousands of years before present using the weighted mean OSL value for equivalent dose determination (preferred ages in bold); "OSL age, in ka (mean)" is the determined age of the sample in thousands of years before present using the mean OSL value for equivalent dose determination. OSL ages are given in years before A.D. 2010 (the year of age determination), and are reported with a 1-sigma standard deviation of the age uncertainty. Preferred ages (in bold) follow criteria discussed in Swezey and others (2016) for the choice of statistical model that is thought to yield the most accurate OSL age. Following Swezey and others (2016), if the dispersion is <25 percent then the preferred age is that obtained by the weighted mean, and if the dispersion is ≥25 percent then the preferred age is that obtained by the

OSL sample ID	Map unit	Latitude	Longitude	Sample elevation, in meters	Sample depth, in centimeters	Water, in percent	K, in percent	U, in ppm	Th, in ppm	CDA, in Gy/k.y.	Dose rate, in Gy/k.y.	DE, in Gy (MAM)	DE, in Gy (weighted)	DE, in Gy (mean)	nDE (mean)	Dispersion, in percent	OSL age, in ka (MAM)	OSL age, in ka (weighted)	OSL age, in ka (mean)	OSL sample ID
GAW-03	Qs1	32.49416° N	81.19051° W	11	150	2 (22)	0.74±0.03	1.03±0.08	2.73±0.18	0.18±0.01	1.25±0.05	26.8±0.66 28.1±0.33	28.5±1.78 29.9±0.89	29.5±2.11 33.8±1.18	25 (25)	24.4	21.5±1.0 22.6±0.9	22.9±1.7 24.0±1.2	23.7±2.0 27.2±1.4	GAW-03
GAW-04	Qs1	32.49416° N	81.19051° W	11	140	1 (24)	0.71±0.04	0.91±0.06	2.90±0.14	0.18±0.01	1.19±0.04	22.2±0.60 22.8±0.63	24.0±1.17 24.6±1.23	24.5±1.47 24.8±1.49	4 (20)	31.8	18.6±0.1 19.1±0.1	20.1±1.2 20.6±1.2	20.4±1.4 20.8±1.4	GAW-04
GAW-05	Qs1	32.54332° N	81.26128° W	12	152	3 (29)	0.60±0.02	0.66±0.04	1.14±0.10	0.17±0.01	0.85±0.03	23.9±1.08	27.6±1.42	27.8±1.53	29 (30)	21.4	28.2±1.7	32.7±2.1	32.9±2.2	GAW-05
GAW-06	Qs1	32.54423° N	81.26348° W	12	148	2 (30)	0.54±0.01	0.30 ± 0.03	0.66±0.10	0.17±0.01	0.69 ± 0.04	20.0±0.90	22.5±1.26	22.5±1.35	25 (25)	17.1	29.3±2.0	32.9±2.5	32.9±2.7	GAW-06
GAW-07	Qs1	32.54423° N	81.26348° W	12	20	3 (28)	0.65±0.02	0.55±0.04	1.32±0.10	0.19±0.02	0.90 ± 0.03	20.0±0.92	21.7±1.11	21.8±1.16	20 (20)	13.6	22.3±1.3	24.1±1.5	24.2±1.6	GAW-07
GAW-08	Qs1	32.52192° N	81.23143° W	12	96	3 (30)	0.67±0.02	0.58±0.04	1.61±0.10	0.19±0.02	0.92 ± 0.03	27.5±0.96	28.3±1.19	28.3±1.13	23 (25)	20.5	29.9±1.4	30.8±1.6	30.8±1.6	GAW-08
GAW-09	Qs1	32.49084° N	81.19570° W	9	78	6 (37)	0.71±0.02	0.74±0.06	2.91±0.10	0.19±0.02	1.03±0.02	19.1±0.69	22.1±1.23	22.1±1.37	19 (20)	17.1	18.5±0.1	21.5±1.3	21.5±1.4	GAW-09
GAW-10	Qs1	32.48911° N	81.18024° W	8	40	5 (34)	0.62±0.02	0.67±0.06	2.45±0.11	0.16±0.01	0.90 ± 0.03	25.6±1.10	28.2±1.35	30.9±1.70	20 (20)	18.7	28.4±1.5	31.3±1.8	34.3±2.2	GAW-10
GAW-11	Qs1	32.48457° N	81.20333° W	9	60	6 (38)	0.53±0.02	0.43±0.06	1.14±0.08	0.19±0.02	0.73±0.03	7.4±0.37	8.9±0.49	8.9±0.46	20 (20)	32.1	10.2±0.7	12.2±0.8	12.2±0.8	GAW-11
GAW-12	Qs1	32.42373° N	81.15730° W	8	80	2 (32)	0.51±0.02	0.43 ± 0.06	1.24±0.08	0.19±0.02	0.74 ± 0.03	9.8±0.47	14.2±0.75	9.9 ± 0.56	18 (20)	17.4	13.3±0.7	19.2±1.2	13.4±1.0	GAW-12
GAW-13	Qs1	32.43740° N	81.14857° W	8	90	4 (31)	0.66±0.03	0.67±0.06	2.09±0.02	0.19±0.02	0.96 ± 0.05	8.3±0.43	9.8±0.54	11.8±0.59	17 (20)	21.3	8.6±0.5	10.3±0.7	12.3±0.9	GAW-13
GAW-14	Qs2	32.44127° N	81.12888° W	8	70	8 (32)	0.79±0.02	0.96±0.07	3.08±0.10	0.19±0.02	1.21±0.02	27.0±1.00	29.3±1.29	30.3±5.12	20 (20)	22.8	22.3±1.0	24.2±1.2	25.0±1.4	GAW-14
GAW-28	Qsmp3	32.54692° N	81.25918° W	12	84	16 (29)	1.80±0.02	2.7±0.06	10.6±0.23	0.19±0.02	2.74±0.06	58.3±4.84	65.8±5.73	66.1±5.68	30 (30)	13.7	20.9±1.8	23.6±2.1	23.7±2.1	GAW-28
GAW-29	Qs3	32.54774° N	81.25823° W	12	61	15 (42)	0.49±0.02	2.06±0.12	7.35±0.23	0.19±0.02	1.32±0.04	43.8±4.03	52.4±4.45	57.4±7.58	29 (30)	15.1	33.2±3.2	39.7±3.6	43.5±5.9	GAW-29
GAW-30	Qs1	32.55597° N	81.27906° W	8	549	1 (27)	0.56±0.02	0.51±0.06	1.93±0.22	0.18±0.01	0.86 ± 0.06	24.0±0.50	26.2±0.84	31.9±1.16	30 (30)	13.2	27.9±1.9	30.5±2.2	37.1±2.8	GAW-30
GAW-31	Ngsm	32.55597° N	81.27906° W	8	640	15 (55)	1.33±0.05	3.58±0.21	14.1±0.60	0.16±0.01	2.37±0.08	>110	>102	>88	10 (10)	20.9	>46	>43	>37	GAW-31
GAW-36	Qs1	32.50996° N	81.22414° W	11	82	3 (24)	0.42±0.01	0.58±0.05	2.38±0.17	0.19±0.02	0.80±0.04	17.3±1.04	18.6±1.21	21.5±1.46	20 (20)	15.6	21.7±1.6	23.3±1.9	26.9±2.2	GAW-36
GAW-37	Qs3	32.48911° N	81.16963° W	8	183	6 (25)	0.50±0.01	0.41±0.05	1.25±0.17	0.16±0.01	0.73±0.05	75.7±5.45	79.0±6.72	88.4±7.34	19 (19)	16.3	104±10	108±12.0	121±13	GAW-37

Table 2. Dinoflagellate cyst species identification results and age estimates from samples R6709 F and R6709 A in drill core C2; sample depth locations within drill core C2 are shown in figure 2. The results provide the lower Miocene age estimate for the stratigraphic unit Nsm shown in figures 2 and 3. ["USGS sample ID" is the U.S. Geological Survey sample identification number; "Surface elevation of drill core, in meters" is elevation above sea level; "Sample depth in drill core, in meters" is the sample depth

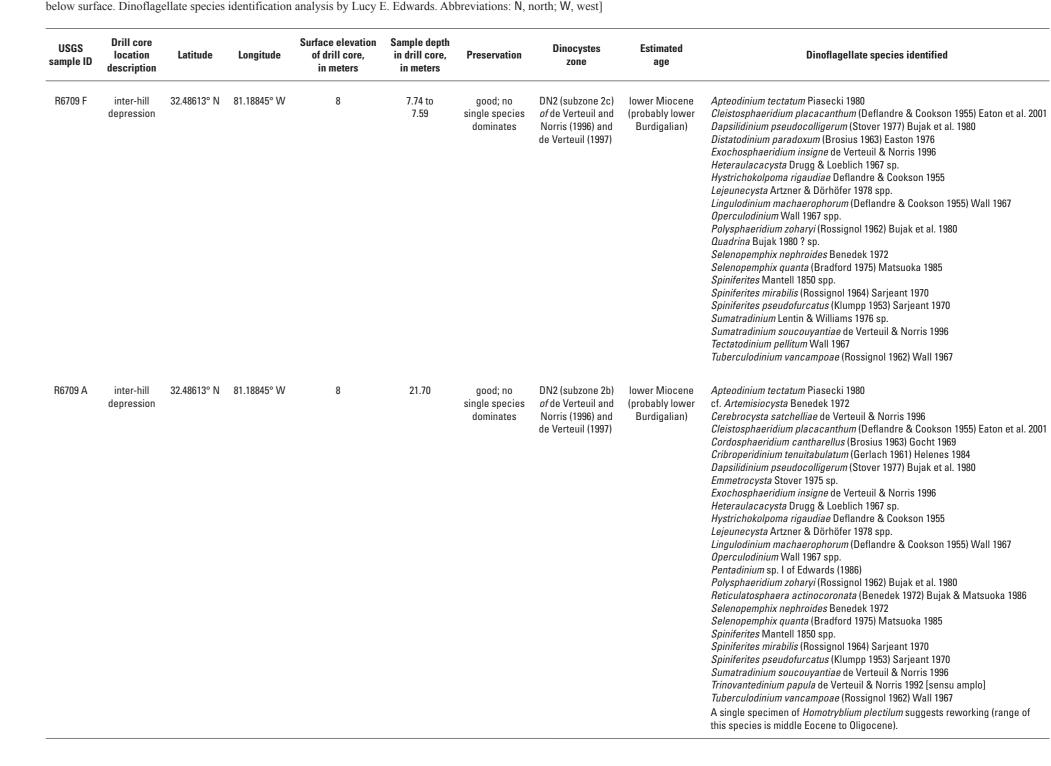


Table 3. Radiocarbon sample data and age results from vibracore (C3) and gouge core (C1). [Core locations are shown on maps A and B. ¹⁴C analyses by John P. McGeehin, Explanation of table columns are as follows: "USGS sample ID" is the U.S. Geological Survey sample identification number from the radiocarbon laboratory in Reston, Va.; "Material dated" is the sample material that was used for radiocarbon dating; "Surface elevation of core, in meters" is elevation above sea level; "Sample depth in core, in meters" is the sample depth below surface; "d13C, in per mil (%)" is the isotope carbon-13 (13C) value used to correct radiocarbon ages due to isotope fractionation, according to Stuiver and Polach (1977); "Age, in ¹⁴C years BP" is the sample age in radiocarbon years before present with a 2-sigma standard deviation of age uncertainty using the Libby half-life of 5,568 years, and 0 years BP being equivalent to A.D. 1950; "Age, in cal. years BP" is the sample age in calibrated years before present]

USGS sample ID	Core	Map unit	Core location description	Latitude	Longitude	Material dated	Surface elevation of core, in meters	Sample depth in core, in meters	d ¹³ C, in per mil (‰)	Age, in ¹⁴ C years BP	Age, in cal years BP
WW8887	C3	Qsmp1	inter-hill depression	32.48710° N	81.20855° W	wood	8	0.46-0.48	-25	modern	modern
WW9477	C3	Qsmp1	inter-hill depression	32.48710° N	81.20855° W	bulk sediment	8	1.03-1.05	-29.6	887±35	910–731
WW8886	C3	Qsmp1	inter-hill depression	32.48710° N	81.20855° W	wood	8	1.81–1.83	-25	5,060±30	5,895–5,667
WW9429	C3	Qsmp1	inter-hill depression	32.48710° N	81.20855° W	bulk sediment	8	2.13–2.14	-28.3	8,275±30	9,403–9,135
WW8888	C1	Qsmp4	fluvial channel	32.48282° N	81.15867° W	wood	5	1.37	-25	41,890±930	46,841–43,85

REFERENCES CITED

Bartram, W., 1791, Travels through North and South Carolina, Georgia, east and west Florida, the Cherokee country, the extensive territories of the Muscogulges, or Creek Confederacy, and the country of the Chactaws: New York, Penguin Books, 414 p. [Republished in 1996.] Bernhardt, C., Swezey, C.S., and Schultz, A.P., 2012, Palynological studies reveal Holocene climate changes in a forested flood plain wetland, Savannah River

valley, South Carolina (USA) [abs.]: Geological Society of America Abstracts

with Programs, v. 44, no. 7, p. 423. [Also available at https://gsa.confex.com/

Blackwelder, B.W., and Ward, L.W., 1979, Stratigraphic revision of the Pliocene deposits of North and South Carolina: South Carolina Geological Survey,

Geologic Notes, v. 23, no. 1, p. 33–49. Christensen, N.L., 2000, Vegetation of the southeastern Coastal Plain, in Barbour, M.G., and Billings, W.D., eds., North American terrestrial vegetation, second edition: Cambridge, United Kingdom, Cambridge University Press, p. 397–448. Clark, W.B., and Miller, B.L., 1906. A brief summary of the geology of the Virginia

gsa/2012AM/webprogram/Paper211715.html.]

Coastal Plain, in Ries, H., ed., The clay deposits of the Virginia Coastal Plain: Geological Survey of Virginia Geological Series, Bulletin no. 2, p. 11–24. [Also available at https://www.dmme.virginia.gov/commercedocs/BUL_2.pdf.] Cooke, C.W., 1936, Geology of the Coastal Plain of South Carolina: U.S. Geological Survey Bulletin 867, 196 p., 2 pls. [Also available at http://pubs.er.usgs.gov/

publication/b867.] Cooke, W., 1925, The Coastal Plain, in Physical Geography of Georgia: Georgia Geological Survey Bulletin 42, p. 19–54.

Cook, P.J., and McElhinny, M.W., 1979, A reevaluation of the spatial and temporal distribution of sedimentary phosphate deposits in the light of plate tectonics: Economic Geology, v. 74, no. 2, p. 315–330. [Also available at http://econgeol. geoscienceworld.org/content/74/2/315.abstract.] Dall, W.H., 1898, A table of North American Tertiary horizons, correlated with one

another and with those of western Europe, with annotations: U.S. Geological Survey Annual Report, no. 18, pt. 2, p. 327–348. Dall, W.H., and Harris, G.D., 1892, Correlation papers—Neocene: U.S. Geological Survey Bulletin 84, 349 p., 3 pl. [Also available at http://pubs.er.usgs.gov/

publication/b84.]

de Verteuil, L., 1997, Palynological delineation and regional correlation of lower through upper Miocene sequences in the Cape May and Atlantic City boreholes, New Jersey Coastal Plain: Proceedings of the Ocean Drilling Program, Scientific Results, v. 150X, p. 129–145. [Also available at http://www-odp. tamu.edu/publications/150x SR/11X CHP.PDF.]

de Verteuil, L., and Norris, G., 1996. Miocene dinoflagellate stratigraphy and systematics of Maryland and Virginia: Micropaleontology, v. 42, supplement, 172 p. [Also available at https://www.jstor.org/stable/pdf/1485926.pdf.] Doar, W.R., III, 2008, Geologic map of the Hardeeville NW quadrangle, Jasper County, South Carolina and Effingham County, Georgia: South Carolina

Geological Survey Open File Report 203, 1 sheet, scale 1:24,000. [Also available at http://www.dnr.sc.gov/geology/publications.htm#ofr201.] Doar, W.R., III, 2013a, Geologic map of the Brighton quadrangle, Hampton and Jasper Counties, South Carolina: South Carolina Geological Survey Open File Report 160, 1 sheet, scale 1:24:000. [Also available at http://www.dnr.sc.gov/

geology/publications.htm#ofr151.] Doar, W.R., III, 2013b, Geologic map of the Pineland quadrangle, Hampton and Jasper Counties, South Carolina: South Carolina Geological Survey Open File Report 163, 1 sheet, scale 1:24:000. [Also available at http://www.dnr.sc.gov/ geology/publications.htm#ofr151.]

deposits: Earth-Science Reviews, v. 40, nos. 1–2, p. 55–124, accessed 2017, at http://www.sciencedirect.com/science/article/pii/0012825295000496. Galbraith, R.F., and Laslett, G.M., 1993, Statistical models for mixed fission track ages: Nuclear Tracks and Radiation Measurements, v. 21, no. 4, p. 459–470, accessed 2017, at https://doi.org/10.1016/1359-0189(93)90185-C.

Föllmi, K.B., 1996, The phosphorous cycle, phosphogenesis and marine phosphate-rich

Galbraith, R.F., Roberts, R.G., Laslett, G.M., Yoshida, H., and Olley, J.M., 1999, Optical dating of single and multiple grains of quartz from Jinmium rock shelter, northern Australia—Part I; Experimental design and statistical models: Archaeometry, v. 41, no. 2, p. 339–364, accessed 2017, at https://doi.org/10.1111/ j.1475-4754.1999.tb00987.x.

Goddard, E.N., Trask, P.D., De Ford, R.K., Rove, O.N., Singewald, J.T., Jr., and Overbeck, R.M., 1963, Rock-color chart: New York, Geological Society of Haq, B.U., Hardenbol, J., and Vail, P.R., 1987, Chronology of fluctuating sea levels

http://science.sciencemag.org/content/235/4793/1156. Harper, R.M., 1903, Botanical explorations in Georgia during the summer of 1901–I. Itinerary: The Bulletin of the Torrey Botanical Club, v. 30, no. 5, p. 282–295.

since the Triassic: Science, v. 235, no. 4793, p. 1156–1167, accessed 2017, at

[Also available at http://www.jstor.org/stable/2478554.] Harper, R.M., 1904, Explorations in the Coastal Plain of Georgia during the season of 1902: The Bulletin of the Torrey Botanical Club, v. 31, no. 1, p. 9–27. [Also available at http://www.jstor.org/stable/2478750.] Harper, R.M., 1905, Phytogeographical exploration in the Coastal Plain of Georgia

[Also available at http://www.jstor.org/stable/2478676.] Haug, G.H., Sigman, D.M., Tiedemann, R., Pedersen, T.F., and Sarnthein, M., 1999, Onset of permanent stratification in the subarctic Pacific Ocean: Nature, v. 401, no. 6755, p. 779–782, accessed 2017, at http://www.nature.com/nature/journal/ v401/n6755/full/401779a0.html.

in 1903: The Bulletin of the Torrey Botanical Club, v. 32, no. 3, p. 141–171.

Huddlestun, P.F., 1988, A revision of the lithostratigraphic units of the Coastal Plain of Georgia—The Miocene through Holocene: Georgia Geologic Survey Bulletin 104, 162 p. [Also available at https://epd.georgia.gov/sites/epd.georgia.gov/files/ related files/site page/B-104.pdf.]

Leeth, D.C., and Nagle, D.D., 1996, Shallow subsurface geology of part of the Savannah River alluvial valley in the upper Coastal Plain of Georgia and South Carolina: Southeastern Geology, v. 36, nos. 1–2, p. 1–14. Leigh, D.S., Srivastava, P., and Brook, G.A., 2004, Late Pleistocene braided rivers of the Atlantic Coastal Plain, USA: Quaternary Science Reviews, v. 23, nos. 1–2, p. 65–84, accessed 2017, at http://www.sciencedirect.com/science/article/pii/ S027737910300221X

Lyell, C., 1845, Observations on the white limestone and other Eocene or older Tertiary formations of Virginia, South Carolina, and Georgia: The Quarterly Journal of the Geological Society of London, v. 1, p. 429-442. Malde, H.E., 1959, Geology of the Charleston phosphate area, South Carolina: U.S. Geological Survey Bulletin 1079, 105 p., 5 pls. [Also available at http://

pubs.er.usgs.gov/publication/b1079.]

Holocene inland dunes in Georgia and the Carolinas—Morphology, distribution, age, and paleoclimate: U.S. Geological Survey Bulletin 2069, 32 p. [Also available at http://pubs.er.usgs.gov/publication/b2069.] Maslin, M., Seidov, D., and Lowe, J., 2001, Synthesis of the nature and causes of rapid climate transitions during the Quaternary, in Seidov, D., Haupt, B.J., and Maslin, M., eds., The oceans and rapid climate change—Past, present, and

Markewich, H.W., and Markewich, W., 1994, An overview of Pleistocene and

future: American Geophysical Union Monograph Series, v. 126, p. 9-52, accessed 2017, at http://onlinelibrary.wiley.com/book/10.1029/GM126. Maslin, M.A., Li, X.S., Loutre, M.-F., and Berger, A., 1998, The contribution of orbital forcing to the progressive intensification of northern hemisphere glaciation: Quaternary Science Reviews, v. 17, nos. 4-5, p. 411-426, accessed 2017, at http://www.sciencedirect.com/science/article/pii/S0277379197000474.

McGee, W.J., 1890, The southern extension of the Appomattox Formation: The American Journal of Science, 3d series, v. 40, no. 235, p. 15–41. [Also available at http://www.ajsonline.org/content/s3-40/235/15.full.pdf+html?sid=0c0210effa7-4548-9881-a37b3212f9e8.] McGee, W.J., 1891, The Lafayette Formation: Twelfth Annual Report of the United States Geological Survey to the Secretary of the Interior 1890–'91, pt. 1,

p. 347–521. [Also available at https://pubs.er.usgs.gov/publication/ar12.]

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, N., and Pekar, S.F., 2005, The Phanerozoic record of global sea-level change: Science, v. 310, no. 5752, p. 1293–1298, accessed 2017, at http://www.sciencemag.org/content/310/5752/ 1293.full.pdf?sid=feb21b62-266d-42e4-95fc-14048ea68720. Prescott, J.R., and Hutton, J.T., 1994, Cosmic ray contributions to dose rates for luminescence and ESR dating—Large depths and long-term time variations:

Radiation Measurements, v. 23, nos. 2-3, p. 497-500, accessed 2017, at https://doi.org/10.1016/1350-4487(94)90086-8 Pickering, S.M., and Jones, R.C., 1974, Morphology of aeolian parabolic sand features along streams in southeast Georgia [abs.]: Geological Society of America Abstracts with Programs, v. 6, no. 4, p. 387–388

Prueher, L.M., and Rea, D.K., 2001, Volcanic triggering of late Pliocene glaciation— Evidence from the flux of volcanic glass and ice-rafted debris to the North Pacific Ocean: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 173, nos. 3-4, p. 215-230, accessed 2017, at https://www.sciencedirect.com/

science/article/pii/S0031018201003236. Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Ramsey, C.B., Buck, C.E., Burr, G.S., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., McCormac, F.G., Manning, S.W., Reimer, R.W., Richards, D.A., Southon, J.R., Talamo, S., Turney, C.S.M., van der Plicht, J., and Weyhenmeyer,

C.E., 2009, IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP: Radiocarbon, v. 51, no. 4, p. 1111-1150. [Also available at https://journals.uair.arizona.edu/index.php/radiocarbon/article/view/3569.] Shackleton, N.J., Backman, J., Zimmerman, H., Kent, D.V., Hall, M.A., Roberts, D.G., Schnitker, D., Baldauf, J.G., Desprairies, A., Homrighausen, R., Huddlestun, P., Keene, J.B., Kaltenback, A.J., Krumsiek, K.A.O., Morton, A.C., Murray, J.W., and Westberg-Smith, J., 1984, Oxygen isotope calibration of the onset of

ice-rafting and history of glaciation in the North Atlantic region: Nature, v. 307, no. 5952, p. 620-623, accessed 2017, at http://www.nature.com/nature/journal/ v307/n5952/pdf/307620a0.pdf. Shattuck, G.B., 1901, The Pleistocene problem of the North Atlantic Coastal Plain: Johns Hopkins University Circular, v. 20, no. 152, p. 69–75. Siple, G.E., 1967, Geology and ground water of the Savannah River plant and

vicinity, South Carolina: U.S. Geological Survey Water-Supply Paper 1841, 113 p., 6 pls. [Also available at http://pubs.er.usgs.gov/publication/wsp1841.] Sloan, E., 1908, Catalogue of mineral localities of South Carolina: South Carolina Geological Survey Bulletin 2, ser. 4, 505 p. Stuck, W.M., 1980, Soil survey of Beaufort and Jasper Counties, South Carolina: Washington, D.C., U.S. Department of Agriculture Soil Conservation

Service, 179 p. [Also available at http://www.nrcs.usda.gov/Internet/ FSE_MANUSCRIPTS/south_carolina/beaufort_jasperSC1980/beaufort.pdf.] Stuiver, M., and Polach, H.A., 1977, Discussion—Reporting of ¹⁴C data: Radiocarbon, v. 19, no. 3, p. 355–363, accessed 2017, at https://journals.uair.arizona.edu/index.

php/radiocarbon/article/view/493/498. Stuiver, M., and Reimer, P.J., 1993, Extended ¹⁴C data base and revised CALIB 3.0 ¹⁴C age calibration program: Radiocarbon, v. 35, no. 1, p. 215–230. [Also available at https://doi.org/10.1017/S0033822200013904.]

Swezey, C.S., 2009, Cenozoic stratigraphy of the Sahara, northern Africa: Journal of African Earth Sciences, v. 53, no. 3, p. 89-121. [Also available at http:// www.sciencedirect.com/science/article/pii/S1464343X08001258.] Swezey, C.S., Fitzwater, B.A., Whittecar, G.R., Mahan, S.A., Garrity, C.P., Alemán

González, W.B., and Dobbs, K.M., 2016, The Carolina Sandhills—Quaternary eolian sand sheets and dunes along the updip margin of the Atlantic Coastal Plain province, southeastern United States: Quaternary Research, v. 86, no. 3, p. 271–286. [Also available at https://doi.org/10.1016/j.yqres.2016.08.007.] Swezey, C.S., Schultz, A.P., Alemán González, W.B., Bernhardt, C.E., Doar, W.R., III, Garrity, C.P., Mahan, S.A., and McGeehin, J.P., 2013, Quaternary eolian dunes in the Savannah River Valley, Jasper County, South Carolina, USA: Quaternary Research, v. 80, no. 2, p. 250–264. [Also available at http://www.

Van Sickel, W.A., Kominz, M.A., Miller, K.G., and Browning, J.V., 2004, Late Cretaceous and Cenozoic sea-level estimates—Backstripping analysis of borehole data, onshore New Jersey: Basin Research, v. 16, no. 4, p. 451-465, accessed 2017, at http://onlinelibrary.wiley.com/doi/10.1111/bre.2004.16.issue-4/issuetoc. Veatch, O., and Stephenson, L.W., 1911, Preliminary report on the geology of the Coastal Plain of Georgia: Geological Survey of Georgia Bulletin 26, 466 p. [Also available at https://epd.georgia.gov/sites/epd.georgia.gov/files/related

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